Title

Investigating the familiarity effect in texture segmentation by means of event-related brain potentials

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Abstract

The familiarity effect (FE) refers to the phenomenon that it is easier to find an unfamiliar element on a background of familiar elements than vice versa. In this study, we examined the FE in texture segmentation while recording event-related brain potentials with the aim to find out which processing stages were influenced by familiarity. In two experiments, with different levels of texture homogeneity, the N1, the N2p and the P3 components were investigated. It was found that the FE in texture segmentation is associated with a modulation of the early N1 and of the intermediate N2p component for homogeneous textures. For inhomogeneous (jittered) textures, the FE was found for the intermediate N2p and for the late P3 components, but not for the N1 component. Our findings suggest that increasing texture inhomogeneity shifts the FE occurrence to later processing stages.

Keywords

Familiarity effect; reversed letter effect; texture segmentation; event-related brain potentials; N1; N2p; P3

Abbreviations

FE: familiarity effect; ERP: event-related brain potential

Highlights

- The familiarity effect in texture segmentation was investigated by means of ERPs.
- For homogeneous textures, the FE was related with a modulation of the N1 and N2p.
- For inhomogeneous (jittered) textures, the FE was found for the N2p and P3.

1 Introduction

Perceptual processes are typically described as consisting of two complementary processes. The first process is called pre-attentive and is automatic, stimulus-driven, and determined by simple features of the stimulus (bottom-up); the second process is more flexible, guided by knowledge, experience, and current goals (top-down; e.g., Treisman & Gelade, 1980; Treisman, 1985; Treisman & Gormican, 1988; Wolfe, 1994; Quinlan, 2003). In most perceptual tasks both processes will interact; however, it is assumed that tasks which are sufficiently simple and automatic will involve only the so-called bottom-up component (Julesz, 1981; Treisman & Souther, 1985; Nothdurft, 1991; Turatto & Galfano, 2000; Saiki, Koike, Takahashi & Inoue, 2005; Theeuwes, 2013). Such tasks lead to fast responses and can be performed in an automatic way without much cognitive effort. A well-established example of such a task is texture segmentation. In texture segmentation tasks, the stimulus consists of a multitude of the same or similar elements that make up a texture or group which is processed as a whole (so-called perceptual grouping). The stimulus is shown for an interval in the range from 50 to 150 ms (to prevent eye movements) and is then masked. The participants have to decide whether there was an irregularity (typically a smaller texture embedded in the larger one) or not. In some special cases (e.g., when target and background differ only in one basic feature), the processing can take place in a seemingly purely automatic manner (so-called effortless texture segmentation; Julesz, 1981; Treisman & Souther, 1985; Nothdurft, 1991; Wolfe, 1992; Rieth & Sireteanu, 1994). Given the above description one might expect that performance in texture segmentation is mainly driven by simple sensory attributes, such as contrast and similarity in simple features but unaffected by knowledge and previous experience.

It is therefore quite striking that Meinecke and Meisel (2014) found effects of previous visual experience on performance in texture segmentation tasks. They observed the

so-called familiarity effect (FE) that was first reported by Frith in 1974. The FE describes the phenomenon that it is easier (e.g., higher hit rates and shorter reaction times) to find an unfamiliar element in a background of familiar elements than vice versa. The FE was not only found for letter detection (Frith, 1974; Martin & Pomerantz, 1978; Malinowski & Hübner, 2001; Zhaoping & Frith, 2011), but also for the detection of numerical digits (Krueger, 1984; Shen & Reingold, 2001) and for object detection (Wolfe, 2001). It was shown that the subject's knowledge (i.e., the subject's familiarity with the letter) is critical for the occurrence of an FE (Malinowski & Hübner, 2001; Shen & Reingold, 2001).

Meinecke and Meisel (2014) found the FE in texture segmentation when the target consisted of unfamiliar reversed *N*'s (*И*'s) embedded in a background of familiar *N*'s. Meinecke and Meisel (2014) used presentation times of only 57 ms, suggesting that prior knowledge in the form of familiarity can modulate early stages of visual processing. This finding by Meinecke and Meisel (2014) can be interpreted in different ways. First, it might indicate that participants use simple features that distinguish familiar stimuli from unfamiliar stimuli to reach their superior performance in the case of unfamiliar targets. Second, it might indicate that texture segmentation is not as automatic as thought and that it instead also involves later, knowledge based components of the perceptual process. Third, it could indicate that the influence of visual experience is not restricted to the late stage of perceptual processes but does in fact already modulate early or mid-early processes. To examine those different possibilities, we recorded event-related brain potentials (ERPs) in an FE-producing texture segmentation task, to assess whether the effect of familiarity is restricted to the late stage of the perceptual process or whether it can already be found for the earlier stages.

In particular, we examined which ERP components were modulated by familiarity during texture segmentation. We focused on an early component (the occipital N1), an intermediate component (the posterior N2, the N2p) and a late component (the parietal P3).

The N1 is the first negative ERP component that occurs in visual processing and can be treated as a marker for the early visual analysis. This component depends primarily on automatic stimulus processing (Wijers, Lange, Mulder & Mulder, 1997) and is modulated by spatial attention (Mangun, 1995). Furthermore, it was suggested that the N1 reflects the enhancement of sensory processing due to an early shift of attention to the task-relevant stimulus (Luck, Heinze, Mangun & Hillyard, 1990; Luck, 1995).

The second ERP component that was investigated was the N2p. The N2p is a negative deflection that occurs under posterior electrodes 200 to 330 ms after stimulus onset in detection tasks (Schlaghecken, Meinecke & Schröger, 2001; Berti & Schröger, 2006; Schubö, Wykowska & Müller, 2007; Schaffer, Schubö & Meinecke, 2011). Some authors assume that the N2p reflects visual selection processes (e.g., Luck & Hillyard, 1994; Schubö, 2009). Other authors (e.g., Schubö, Meinecke & Schröger, 2001) suggested that the N2p reflects automatic target detection processing and does not draw on attentional resources.

Another very distinct component that can be found in visual tasks is the P3 that was found to be stronger in target-present trials than in target-absent trials (Luck & Hillyard, 1990; Schlaghecken et al., 2001; Schubö et al, 2001). It was proposed to reflect higher cognitive processes than the earlier components and is related to the processing intensity (Kok, 2001). Moreover, it was found that in texture segmentation tasks the P3 amplitude was affected by the required attentional resources (Schubö et al., 2001). Furthermore, the P3 amplitude is decreased for more difficult tasks (e.g., Kok, 2001; Hagen, Gatherwright, Lopez & Polich, 2006) and, thus, it was shown that the P3 is related to task difficulty. Accordingly, we expected to find a difference in the P3 component between the easier condition with unfamiliar target elements and the more difficult condition with familiar elements.

To summarize, in our study the N1 was treated as a marker for the early visual analysis, the N2p as a marker for the processing in the intermediate time range, and the P3 as a marker for the later processing.

We investigated the FE in texture segmentation, using either the familiar letter *N* or the unfamiliar *И* as target and background elements. In the following, the condition in which the target consists of familiar letters *N* and the background consists of unfamiliar symbols (*И)* is referred to by the term 'familiar target'. The other condition where an unfamiliar symbol is used for the target elements and the familiar symbol is used for the background elements is called the 'unfamiliar target' condition.

Texture segmentation was chosen for two reasons. First, it provided us with the opportunity to test the robustness of the Meinecke and Meisel (2014) finding. Second, the seemingly effortless and quick way in which texture segmentation is carried out also suggests that early processes play an important role. Therefore, using texture segmentation offered us a good opportunity to examine how familiarity modulates early and intermediate sensory processes. Furthermore, our study was the first in that ERPs were used to investigate the mechanisms underlying the FE.

One might argue that the main difference between the standard *N* and the *И* is the orientation of the second stroke of the letter (left-tilted in the case of the standard *N* and right-tilted in the case of the *И*). Therefore, we felt it necessary to test whether such an orientation difference alone could produce the FE. For this reason, two conditions with left- or right-tilted lines as target or background elements were introduced. In total, we compared four conditions (Table 1): (1) A patch of normal *N*'s on a background of *И's* ('familiar target'), (2) a patch of *И*'s on a background of normal *N*'s ('unfamiliar target'), (3) a patch of left-tilted lines on a background of right-tilted lines ('left-tilted lines') and (4) a patch of right-tilted lines on a background of left-tilted lines ('right-tilted lines'). The FE should lead to a

difference between the ‘familiar target’ condition and the ‘unfamiliar target’ condition, which should be the easier one, resulting in higher hit rates, shorter reaction times and lower false alarm rates. We expected to find no differences between the ‘left-tilted lines’ and ‘right-tilted lines’ conditions.

<Table 1 about here>

To summarize, the aim of our study was threefold: First, we wanted to investigate whether the FE in texture segmentation can be replicated. Second, we wanted to examine whether the FE in texture segmentation reflects the influence of knowledge or whether it reflects a preference of the sensory system for one specific visual orientation. Finally and most important, we wanted to employ ERPs to characterize the processing stage at which effects of familiarity could be found in texture segmentation. To answer the first two questions, a pre-test was performed where only behavioral responses were collected. The main question was then investigated by means of two EEG experiments (Experiment 1 and 2). In Experiment 1, we used homogeneous textures, in which the distance between elements remained the same across the display. This principle of equidistance was relaxed in Experiment 2 to make the display more inhomogeneous with the aim of strengthening the FE (Meinecke & Meisel, 2014), because applying a jitter improves the perception of the single elements and thus strengthens the influence of familiarity.

2 Experiment 1

In Experiment 1, four conditions (‘familiar target’, ‘unfamiliar target’, ‘left-tilted lines’, and ‘right-tilted lines’) were investigated. The aims were to replicate the findings by Meinecke and Meisel (2014) that an FE can be produced within a texture segmentation task

and to determine which ERPs and therefore which processing stages are influenced by familiarity. Prior to this, a pre-test was performed to establish the optimal target eccentricity for the EEG experiment.

2.1 Pre-test

2.1.1 Methods pre-test

Participants. Twenty-three subjects (mean age 20.9 ± 2.2 years; two male; 21 female) participated in the pre-test. In all experiments (i.e., in the pre-test and in both EEG experiments), all participants had normal or corrected-to-normal visual acuity, reported no psychological or neurological diseases and no experience with the Cyrillic alphabet. The latter would have been an exclusion criterion, because the letter *И* is part of the Cyrillic alphabet and thus familiar to persons who are familiar with this alphabet. All participants (for this and the other reported experiments) gave their written and informed consent and received course credits for participation. This and the other reported experiments were carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Stimuli. The display consisted of 45 elements per row and 29 elements per column. The target was a patch of 3x3 elements presented at -7.3°, -3.7°, 0°, +3.7° or +7.3° eccentricity (Figure 1). Only half of the stimuli contained the target stimulus. The elements were black drawings (0.9 cd/m^2) on a light grey background (48.6 cd/m^2). The whole stimulus extended 10.2° of visual angle in horizontal to the left and right side of the fixation point and 6.5° to the upper and lower visual field from the fixation point. The target extended 1.4° in both horizontal and vertical direction. In the pre-test and in Experiment 1, four conditions were investigated: (1) the ‘familiar target’ condition, (2) the ‘unfamiliar target’

condition, (3) the ‘left-tilted lines’ condition, and (4) the ‘right-tilted lines’ condition. An overview of the conditions used in all experiments can be found in Table 1.

<Figure 1 about here>

Apparatus. The participants were seated in an electrically shielded and sound-attenuated booth in a comfortable chair with response buttons under their left and right index fingers. Stimuli were presented on a 21 inch computer monitor (Philips 201B4) with a refresh rate of 85 Hz and a resolution of 1600 x 1200 pixels. The distance between observer (midpoint between the two eyes) and the monitor was 1.10 m. Stimulus presentation was controlled by MATLAB programs using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Luminance measurements were conducted with a Minolta luminance meter (model LS110). Visual acuity was tested with a Rodenstock R22 vision tester (stimulus no. 212).

Procedure. The pre-test consisted of 28 blocks, seven for each condition. In each block, the target was presented seven times at each of the five target positions (-7.3°, -3.7°, 0°, +3.7°, +7.3°), resulting in 49 targets per position and condition. Half of the trials contained no target. The four conditions (‘familiar target’, ‘unfamiliar target’, ‘left-tilted lines’, ‘right-tilted lines’) were presented in blocks of random order for the participants. Each trial started with a fixation point presented for 741 ms, followed by the stimulus. Mean hit rates, false alarm rates and reaction times were recorded. Responses were made by either pressing the left or the right response button (left: no target; right: target). The participants were instructed to keep the false alarm rates as low as possible. In the pre-test, the stimulus presentation time was specified individually for each subject so that the mean hit rates were between 30 and 85% and equal for the ‘familiar target’ and ‘unfamiliar target’ conditions as

well as for the ‘left-tilted lines’ and ‘right-tilted lines’ conditions. The stimuli were followed by a mask (superposition of target and distractor elements). The entire stimulus duration interval lasted for 1000 ms (i.e., the presentation time for the mask was individually adjusted to ensure that the whole presentation time of both the stimulus and the mask was the same for all participants). The ‘familiar target’ and the ‘unfamiliar target’ conditions were much harder than the ‘left-tilted lines’ and ‘right-tilted lines’ conditions, resulting in longer presentation times needed to achieve mean hit rates between 30% and 85%. The presentation times were 119.3 ± 15.2 ms for the ‘familiar target’ and the ‘unfamiliar target’ conditions and 58.8 ± 17.3 ms for the ‘left-tilted lines’ and ‘right-tilted lines’ conditions.

***Data analysis*.** Analyses of Variance (ANOVAs) for repeated measurements were computed. If necessary, sphericity violations (determined by Mauchly’s test of sphericity; Mauchly, 1940) were corrected by adjusting the degrees of freedom with the procedure by Greenhouse and Geisser (1959). Partial eta-squares were used as measures of the effect sizes. The factors were target type (‘familiar target’ vs. ‘unfamiliar target’ or ‘left-tilted lines’ vs. ‘right-tilted lines’) and eccentricity (‘-7.3°’, ‘-3.7°’, ‘0°’, ‘+3.7°’, ‘+7.3°’). The dependent variables were hit rates and reaction times (for the target-present trials). If necessary, post-hoc t-tests (two-tailed) were computed with adjusted alpha levels according to the Bonferroni correction. For the false alarm rates, paired-sample t-tests were computed. All statistical analyses were performed using IBM SPSS Statistics 22.

2.1.2 Results pre-test

For the hit rates in the ‘familiar target’ and the ‘unfamiliar target’ conditions, a main effect of target type ($F(1, 22) = 17.59$, $p < .001$, $\eta_p^2 = .44$), a main effect of eccentricity ($F(2.92, 64.24) = 75.33$, $p < .001$, $\eta_p^2 = .77$) and an target type * eccentricity interaction ($F(4,$

88) = 10.27, $p < .001$, $\eta_p^2 = .32$) were found. Post-hoc t-tests showed a significant difference between the 'familiar target' and the 'unfamiliar target' conditions only at the retinal eccentricities of -3.7° ($t(22) = -4.57$, $p < .001$) and +3.7° ($t(22) = -4.66$, $p < .001$). At these eccentricities, the hit rates were higher in the 'unfamiliar target' condition than in the 'familiar target' condition, providing support for the FE. As can be seen in Figure 2, we were at floor at the other eccentricities so that we cannot conclude that no FE occurred at these target positions. The main effect of eccentricity reflects the so-called central performance drop (Kehrer, 1989). This means that the target detection was better at ±3.7° eccentricity than at the more foveal and more peripheral positions. The central performance drop is generally found when orientation differences are evaluated and can be treated as a marker for the automatic visual processing (Meinecke & Meisel, 2014). For the reaction times (in the target-present trials), a main effect of target type ($F(1, 22) = 22.75$, $p < .001$, $\eta_p^2 = .51$) and a main effect of eccentricity ($F(3, 65.98) = 8.98$, $p < .001$, $\eta_p^2 = .29$) were found. The reaction times were longer in the 'familiar target' than in the 'unfamiliar target' condition for all eccentricities, reflecting the FE. As for the hit rates, the main effect reflects a central performance drop (shortest reaction times at ±3.7°). For the false alarm rates, an FE between the 'familiar target' and the 'unfamiliar target' conditions was found as well ($t(22) = 2.66$, $p = .014$).

<Figure 2 about here>

For the hit rates in the 'left-tilted lines' and 'right-tilted lines' conditions, a main effect of eccentricity ($F(1.87, 41.11) = 37.82$, $p < .001$, $\eta_p^2 = .92$) was found, but no main effect of target type ($p = .156$) nor an interaction with the factor target type ($p = .061$) were found. Again, a central performance drop (highest hit rates at ±3.7°) was found. For the

reaction times and false alarm rates, no differences between the ‘left-tilted lines’ and ‘right-tilted lines’ conditions were found (reaction times: $p = .114$; false alarm rates: $p = .076$).

2.1.3 Discussion pre-test

In the pre-test, we replicated the findings by Meinecke and Meisel (2014) that an FE can occur in texture segmentation when the target or background elements consist of either the letter *N* or *H*. The highest hit rates and a strong FE were found at ±3.7° eccentricity. At these eccentricities, the hit rates were higher and the reaction times and false alarm rates were lower in the ‘unfamiliar target’ condition than in the ‘familiar target’ condition, reflecting the FE. In the control experiment, no differences between the ‘left-tilted lines’ and ‘right-tilted lines’ conditions were found. These findings provide evidence that the FE does not simply reflect differences in the processing of left-tilted lines versus right-tilted lines. More importantly, the findings informed us about the optimal conditions to elicit the FE. They thus provide an excellent basis for our EEG experiments.

2.2 Methods Experiment 1

2.2.1 Participants

From initially 23 subjects, data from 19 subjects were entered into the final analysis (mean age 21.5 ± 3.1 years; two male; 17 female). We adjusted the presentation times to achieve comparable hit rates (above 70%) across both conditions, while using the same presentation times for both, the ‘familiar target’ condition and the ‘unfamiliar target’ condition. Nevertheless, the hit-rate for the ‘familiar target’ condition dropped below 70% in four subjects during the experiment and these subjects were excluded from further analysis. All participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971).

2.2.2 Apparatus

The apparatus was the same as in the pre-test, complemented by additionally recording an EEG, using 64 active electrodes (actiCap, Brain Products, Germany) positioned according to the international 1020 system. All electrodes were referenced online to FCz and re-referenced offline to the average of the left and right mastoids. The sampling rate was 500 Hz. Electrode impedances were kept below 25 kΩ. To control for blinks and eye movements, vertical and horizontal EOGs were recorded from above the right eyebrow, from below the right eye and from the outer canthi of the eyes. Data analysis was conducted with the Brain Vision Analyzer 2.0 (Brain Products, Germany).

2.2.3 Stimuli

The stimuli were the same as in the pre-test, but the targets occurred only at either -3.7°or +3.7° eccentricity.

2.2.4 Procedure

The target appeared in 50% of the trials. The stimuli were presented in blocks. In each block, the target could occur 15 times at each position. Seven blocks were presented for each condition, resulting in 105 targets per position in each condition. The order of the conditions was counterbalanced between the participants. The time course of the experiment is shown in Figure 3. Each trial started with a fixation point presented for 741 ms, followed by the stimulus. The stimulus presentation times were adjusted individually for each participant with the goal to find a presentation time where the hit rates for all conditions were at ceiling while keeping the presentation times as short as possible. This was done with the aim to achieve the

same number of hit trials to have the same signal-to-noise ratio in the ERPs for both conditions. Thus, for a given participant the presentation time remained the same across all four conditions ('familiar target', 'unfamiliar target', 'left-tilted lines', 'right-tilted lines'). The mean presentation times were 114.6 ± 14.6 ms. The maximally allowed presentation time was 141.2 ms. Limitations of this procedure are described in the general discussion. Each participant received 16 practice trials (four for each condition) at the start of the experiment. Each participant performed 16 practice trials (four for each condition). Note, that no mask was used in the EEG experiment to ensure that the ERP responses to the stimuli were not contaminated by responses to the mask stimulus

<Figure 3 about here>

2.2.5 Data processing and analysis

The EEG was averaged offline for epochs of 1100 ms, starting 200 ms prior to stimulus onset and ending 900 ms after stimulus offset. The EEG was filtered with a 30 Hz low-pass filter and a 0.1 Hz high-pass filter. Trials containing eye movements were excluded from further analysis. Trials containing blinks were corrected according to the procedure by Gratton, Cole and Donchin (1983). Trials with voltages exceeding 70 µV, voltage steps between two sampling points exceeding 50 µV/ms, voltages lower than 0.1 µV in 100 ms and absolute voltage differences exceeding 300 µV in each segment were removed. Trials with incorrect or no responses were excluded as well.

EEG data was averaged for target-present and target-absent trials and was collapsed for left and right target location. ERP analysis was carried out in two steps: First, the ERP latencies were estimated for the peak maxima in pre-defined time windows, in which the

ERPs usually occur (120-180 ms for the N1, 240-330 ms for the N2p, and 350-520 ms for the P3; e.g., Eimer, 1993; Luck & Hillyard, 1994; Schaffer et al., 2011). Second, mean amplitudes were calculated in an interval around the individual peak maximum for the given ERP for this person. This interval was set to ±10 ms around the peak maximum for the narrow N1 and N2p components, and around ±50 ms for the broader P3 component. The ERPs (latencies and amplitudes) were each estimated under three electrodes under which they can be found usually. The N1was estimated under O1, Oz, and Oz, the N2p under PO3, POz, and PO4, and the P3 under P1, Pz, and P2.

Data analysis consisted of two parts: First, the analysis of the behavioral data and second, the analysis of the ERPs. For the analysis of the behavioral data, mean hit rates, reaction times and false alarm rates were computed for the 'familiar target', 'unfamiliar target' and the 'left-tilted lines' and 'right-tilted lines' conditions, collapsed across target presentations in the left or right visual field. From these mean hit rates and false alarm rates, sensitivities *d'* were calculated as the difference between the z-transformed hit rates and false alarm rates. Statistical analysis was performed for the reaction times (for the target-present trials) and sensitivities only. To compare the mean values between both the 'familiar target' and the 'unfamiliar target' conditions and between the 'left-tilted lines' and 'right-tilted lines' conditions, paired-sample t-tests were computed, separately for the sensitivities and reaction times

For ERP evaluation, ANOVAs with the factors target type ('familiar target' vs. 'unfamiliar target' or 'left-tilted lines' vs. 'right-tilted lines') and target presence (target-absent vs. target-present) were computed, separately for the N1, N2p and P3 components. Additionally, to compare the ERPs between all four target types, ANOVAs with the factor target type ('familiar target', 'unfamiliar target', 'left-tilted lines', and 'right-tilted lines')

were computed, separately for both the target-absent and the target-present trials and separately for each component.

2.3 Results Experiment 1

2.3.1 Behavioral data in the EEG experiment

For the sensitivity, the FE was found. The sensitivity was significantly lower for the 'familiar target' than for the 'unfamiliar target' condition ('familiar target': 3.2 ± 0.68 'unfamiliar target': 3.8 ± 0.54; $t(18) = -4.56$, $p < .001$). For the 'left-tilted lines' and 'right-tilted lines' conditions, no differences were found for sensitivity ($p = .190$). For the reaction times, no significant differences were found, neither between the 'familiar target' and the 'unfamiliar target' ($p = .152$) conditions nor between the 'left-tilted lines' and the 'right-tilted lines' condition ($p = .436$).

2.3.2 EEG data

The ERP amplitudes and latencies for all four conditions that were investigated in Experiment 1 are summarized in Table 1.

<Table 1 about here>

N1 amplitude. For the 'familiar target' and the 'unfamiliar target' conditions, a main effect of target type was found ($F(1, 18) = 7.24$, $p = .015$, $\eta_p^2 = .29$), reflecting stronger N1 amplitudes in the 'unfamiliar target' condition than in the 'familiar target' condition. For the 'left-tilted lines' and 'right-tilted lines' conditions, no significant effects were obtained (all $p > .148$). A comparison between all the four target types ('familiar target', 'unfamiliar target',

'left-tilted lines', and 'right-tilted lines') showed no significant differences between the N1 amplitudes for the target-absent trials or the target-present trials (both $p > .417$).

N1 latency. For the 'familiar target' and the 'unfamiliar target' conditions, no significant effects were obtained (all $p > .310$). For the 'left-tilted lines' and 'right-tilted lines' conditions, no significant effects were obtained (all $p > .141$) as well. A comparison between all the four target types ('familiar target', 'unfamiliar target', 'left-tilted lines', and 'right-tilted lines') showed no significant differences between the N1 latencies for the target-absent trials or the target-present trials (both $p > .384$).

N2p amplitude. For the 'familiar target' and the 'unfamiliar target' conditions, both a main effect of target type ($F(1, 18) = 4.50$, $p = .048$, $\eta_p^2 = .20$) and a main effect of target presence ($F(1, 18) = 14.41$, $p < .001$, $\eta_p^2 = .45$) were found. The N2p amplitude was stronger in the target-absent than in the target-present trials and stronger in the familiar target condition than in the unfamiliar target condition (Figure 4). For the 'left-tilted lines' and 'right-tilted lines' conditions, only main effect of target presence ($F(1, 18) = 81.89$, $p < .001$, $\eta_p^2 = .82$) was found, but no main effect of target type nor an interaction with the factor target type was obtained. The N2p amplitudes were stronger in the target-absent trials than in the target-present trials (Figure 5) for both the 'left-tilted lines' and the 'right-tilted lines' conditions.

<Figure 4 about here>

<Figure 5 about here>

A comparison between all the four target types (‘familiar target’, ‘unfamiliar target’, ‘left-tilted lines’, and ‘right-tilted lines’) revealed a main effect of target type for the target-present trials ($F(2.92, 52.50) = 21.27$, $p < .001$, $\eta_p^2 = .54$). The N2p for the target-present trials differed between all the four target types except between the ‘left-tilted lines’ and ‘right-tilted lines’ conditions and was less distinct in the ‘left-tilted lines’ and ‘right-tilted lines’ conditions than in the ‘familiar target’ and the ‘unfamiliar target’ conditions. For the target-absent trials, no significant difference between any of the four target types was found ($p = .294$).

N2p latency.

For the ‘familiar target’ and the ‘unfamiliar target’ conditions, only a main effect of target presence ($F(1, 18) = 6.22$, $p = .023$, $\eta_p^2 = .26$) was found, reflecting longer N2p latencies in the target-absent than in the target-present trials. For the ‘left-tilted lines’ and ‘right-tilted lines’ conditions, only a main effect of target presence ($F(1, 18) = 25.60$, $p < .001$, $\eta_p^2 = .59$) was found. The latencies were longer in the target-absent than in the target-present trials. A comparison between all four target types (‘familiar target’, ‘unfamiliar target’, ‘left-tilted lines’, and ‘right-tilted lines’) revealed a main effect of target type for the target-absent trials ($F(3, 54) = 8.65$, $p < .001$, $\eta_p^2 = .33$). The N2p latency for the target-absent trials was longer for the ‘left-tilted lines’ and ‘right-tilted lines’ conditions than for the ‘familiar target’ and ‘unfamiliar target’. For the target-present trials, no significant difference between any of the four target types was found ($p = .966$).

P3 amplitude. For the P3 in the ‘familiar target’ and the ‘unfamiliar target’ conditions, only a main effect of target presence was found ($F(1, 18) = 67.79$, $p < .001$, $\eta_p^2 = .79$), reflecting stronger P3 amplitudes in the target-present trials than in the target-absent trials. For the ‘left-tilted lines’ and ‘right-tilted lines’ conditions, a main effect of target presence was found as well ($F(1, 18) = 109.93$, $p < .001$, $\eta_p^2 = .86$), also reflecting stronger

P3 amplitudes in the target-present trials than in the target-absent trials. A comparison between all the four target types revealed no significant differences, neither for the target-absent trials nor for the target-present trials (both $p > .123$).

P3 latency. For the P3 in the 'familiar target' and the 'unfamiliar target' conditions only a main effect of target presence was found ($F(1, 18) = 5.05$, $p = .037$, $\eta_p^2 = .22$), reflecting longer P3 latencies in the target-absent than in the target-present trials. For the 'left-tilted lines' and 'right-tilted lines' conditions, only a main effect of target presence was found as well ($F(1, 18) = 19.81$, $p < .001$, $\eta_p^2 = .52$), also reflecting longer P3 latencies in the target-absent than in the target-present trials. A comparison between all the four target types ('familiar target', 'unfamiliar target', 'left-tilted lines', and 'right-tilted lines') revealed a main effect of target type for the target-present trials ($F(3, 32.37) = 5.90$, $p = .008$, $\eta_p^2 = .25$). The P3 latency for the target-present trials was shorter for the 'left-tilted lines' and 'right-tilted lines' conditions than for the 'familiar target' and 'unfamiliar target'. For the target-absent trials, no significant difference between any of the four target types was found ($p = .855$).

2.4 Discussion Experiment 1

The only ERP components that were modulated by familiarity were the N1 and the N2p, but not the late P3 component. This means that only the processing in the early and in the intermediate time range was affected by familiarity. In order to exclude the possibility that the FE in our study was too subtle to have a measurable effect on the P3 component and to investigate whether this would change when strengthening the FE, a second experiment was conducted in which the effect of familiarity was strengthened.

3 Experiment 2

In Experiment 1, the FE in a texture segmentation task did not significantly modulate the N1 or the P3 components. This raised the question whether the FE in Experiment 1 may have been too small. For this reason, we aimed to introduce a more pronounced FE in Experiment 2. To achieve this, we introduced a spatial jitter between the elements of the display. In general, applying a jitter decreases detection performance in texture segmentation (Kehrer, 1987; Gurnsey & Browse, 1989), because it impedes grouping processes. The jitter enhances the perception of the single elements (in our case the *N*'s and *И*'s) and thus enhances the influence of familiarity and thus the strength of the FE (Meinecke & Meisel, 2014). Given that we have already established that orientation differences alone are not responsible for the FE in texture segmentation the 'left-tilted lines' and 'right-tilted lines' conditions were dropped from Experiment 2.

3.1 Methods Experiment 2

3.1.1 Participants

18 subjects (mean age 21.1 ± 3.7 years; two male; 16 female) participated in the experiment. As in Experiment 1, all participants were right-handed.

3.1.2 Apparatus

The apparatus was the same as in Experiment 1.

3.1.3 Stimuli

The stimuli consisted of 29 rows and 45 columns (resulting in 1305 elements; Figure 6). The elements were *N*'s or *И*'s with a width of 0.27°, spaced with a distance of 0.20°. The

targets consisted of 3 x 3 elements, resulting in a target width of 1.21°. A spatial jitter of 0.03° was applied. The targets occurred on the horizontal line along the fixation point and their center appeared at either ±2.8° or ±3.3° to the left or right visual field. We generated two stimuli with a different jitter for each retinal eccentricity, resulting in eight target stimuli for each of the two ('familiar target' and 'unfamiliar target') conditions. Again, we generated stimuli for the target-absent trials consisting only of background elements. As in Experiment 1, the target and background elements were black drawings (0.9 cd/m^2) on a grey background of 48.6 cd/m^2.

<Figure 6 about here>

3.1.4 Procedure

The procedure was slightly different from that in Experiment 1. We used a fixed stimulus presentation time of 117.6 ms to exclude influences of various presentation times on the ERPs. A pre-test showed that this value was optimal to ensure that the task was neither too easy nor too difficult and sufficient to produce an FE. The two conditions were presented in separate blocks. Within each block, the target was present in 50% of all trials. The target was presented 14 times at each of the four eccentricities in each block. The participants were allowed as many breaks as they needed between the blocks. The number of blocks was determined individually depending on the participant's individual hit rates. In the easier condition with higher hit rates, all subjects conducted seven blocks. In the harder condition, the subjects conducted seven to ten blocks. This was done to ensure that similar number of correct target-present trials (hit trials) were available for analysis in each condition. Each participant conducted eight practice trials (two repetitions per target position) at the start of

the experiment. As in the previous experiments, the participants were instructed to keep the false alarm rates as low as possible.

3.1.5 Data analysis

The data analysis was largely conducted in the same way as in Experiment 1. However, in Experiment 2 we had only two different conditions. For the statistical analysis, the behavioral data (sensitivities and reaction times) as well as the ERP data from all eccentricities were combined. Again, mean amplitudes of the N1, N2p and P3 component for the same electrodes and time windows as in Experiment 1 were computed. Additionally, a later P3 time window (between 520 and 750 ms) was analyzed.

To compare both experiments, mixed-factor ANOVAs with the within-subject factor target type ('familiar target' vs. 'unfamiliar target') and the between-subjects factor experiment ('1: without jitter' vs. '2: with jitter') were computed for both the behavioral and the EEG data. The EEG data was compared separately for the target-absent trials and the target-present trials.

3.2 Results Experiment 2

3.2.1 Behavioral data

The behavioral data confirmed that a strong FE could be produced with the jittered stimuli: The sensitivity was significantly higher in the 'unfamiliar target' condition (3.6 ± 0.8) than in the 'familiar target' condition (2.5 ± 0.6; $t(17) = -7.13$, $p < .001$). The reaction times (for the target-present trials) were significantly shorter in the 'unfamiliar target' condition (677.0 ± 96.3 ms) than in the 'familiar target' condition (734.5 ± 104.9 ms; $t(17) = 4.11$, $p = .001$).

3.2.2 EEG data

The ERP amplitudes and latencies for all four conditions that were investigated in Experiment 2 are summarized in Table 1.

<Table 2 about here>

***N1 amplitude*.** For the N1 amplitude, no significant effects were found (all $p > .07$).

***N1 latency*.** For the N1 latency, also no significant effects were found (all $p > .43$).

***N2p amplitude*.** For the N2p amplitude, a main effect of target type ($F(1, 17) = 15.95$, $p < .001$, $\eta_p^2 = .48$), a main effect of target presence ($F(1, 17) = 16.05$, $p < .001$, $\eta_p^2 = .49$), and a target type * target presence interaction ($F(1, 17) = 7.01$, $p = .017$, $\eta_p^2 = .29$) were found. Post-hoc t-tests showed that the difference between the 'familiar target' and the 'unfamiliar target' condition was only significant for the target-present trials ($t(17) = -4.01$, $p = .001$). They slightly missed significance for the target-absent trials after Holm-Bonferroni correction ($p = .014$, $\alpha_{adj} = .013$). For the target-present trials, the N2p was stronger for the 'familiar target' than for the 'unfamiliar target' condition. For the 'unfamiliar target' condition, a significant difference between the target-absent and the target-present trials was found ($t(17) = -4.03$, $p = .001$; Figure 7). For the 'familiar target' condition, the difference between the target-absent and the target-present trials missed significance ($p = .023$, $\alpha_{adj} = .013$).

<Figure 7 about here>

***N2p latency*.** For the N2p latency, no significant effects were found (all $p > .09$).

***P3 amplitude*.** For the P3 amplitude, a main effect of target type ($F(1, 17) = 5.98$, $p = .03$, $\eta_p^2 = .26$), a main effect of target presence ($F(1, 17) = 88.86$, $p < .001$, $\eta_p^2 = .84$), and a target type * target presence interaction ($F(1, 17) = 17.95$, $p < .001$, $\eta_p^2 = .51$) were found. Post-hoc t-tests showed that the P3 was stronger for the target-present trials than for the target-absent trials in both the 'familiar target' and the 'unfamiliar target' condition ('familiar target': $t(17) = -7.00$, $p < .001$; 'unfamiliar target': $t(17) = -9.91$, $p < .001$). The difference between the 'familiar target' and the 'unfamiliar target' condition (the FE) was only significant for the target-present trials ($t(17) = -3.60$, $p = .002$).

***P3 latency*.** For the P3 latency, only a main effect of target presence was found ($F(1, 17) = 5.67$, $p = .029$, $\eta_p^2 = .25$). The P3 latency was longer in the target-present trials than in the target-absent trials in both conditions.

3.2.3 Comparison of Experiment 1 and Experiment 2

Despite some differences in the experimental setup it is informative to compare the sensitivities and the ERPs of the two experiments. For the sensitivity, we found a main effect of target type ($F(1, 35) = 71.11$, $p < .001$, $\eta_p^2 = .67$; reflecting the FE), a main effect of experiment ($F(1, 35) = 4.57$, $p = .017$, $\eta_p^2 = .15$) and a target type * experiment interaction ($F(1, 35) = 6.90$, $p = .013$, $\eta_p^2 = .17$). Post-hoc t-tests showed that the sensitivities were only significantly different between Experiment 1 (without jitter) and Experiment 2 (with jitter) for the 'familiar target' condition ($t(35) = 3.51$, $p = .001$), but not for the 'unfamiliar target' condition. The only difference between the experiments in the EEG data was found for the latency of the P3 component. For this component, a main effect of experiment ($F(1, 35) = 25.20$, $p = < .001$, $\eta_p^2 = .42$) was found for target-absent trials, reflecting longer P3 latencies

in Experiment 1 than in Experiment 2. For the latencies of the other ERP components and for all ERP amplitudes, no main effects of experiment and no interaction for experiment * target type were found.

3.3 Discussion Experiment 2

In Experiment 2, we disrupted the textures' regularity by applying a spatial jitter to the stimuli. Meinecke and Meisel (2014) showed that this manipulation leads to a strengthened FE. They attributed this to the better perceptibility of single elements (compared to homogeneous textures) leading to a stronger influence of familiarity on the stimulus processing and thus to a more pronounced FE. This was confirmed by the findings of the behavioral data of our second experiment. For the ERP data, the intermediate N2p and the late P3 component were affected by familiarity in Experiment 2. Thus, jittering the textures lead to a later occurrence of the FE. When directly comparing the ERPs of both experiments, the only significant difference was found for the P3 component for the target-absent trials.

Thus, our findings seem to confirm that jittering not only makes grouping harder, but that it also shifts the effect of the familiarity influence to a later processing stage.

4 General discussion

In this study, we examined the FE in texture segmentation by means of ERPs. We confirmed that familiarity affects performance in texture segmentation. This has been reported before by Meinecke and Meisel (2014). We confirmed their finding in two further experiments. Additionally, three ERP components that emerge at different time points and that can be assigned to different processing stages were investigated. The earliest ERP component, the N1, was only modulated by familiarity in Experiment 1, in which homogeneous textures were used. The N1 component is often interpreted as an indicator for

the early automatic stimulus processing that only depends on the physical stimulus properties (Wijers et al., 1997). The results of our first experiment contradict this interpretation because we have shown that the N1 is modulated by familiarity for homogeneous textures. Furthermore, it is interesting to compare our N1 findings with the findings by Zhaoping and Frith (2011), who employed eye movement recordings and who observed that the latency of the first saccade was only modulated by familiarity when using sparse search arrays, but not when dense search arrays were used. Zhaoping and Frith (2011) concluded that when the FE is strengthened by using a sparse search array, its effect is observed at an earlier stage. We found a somewhat different pattern. When we increased the strength of the FE by using a jitter, the locus of the FE was shifted to a later processing stage. There is, however, an account which can resolve this apparent contradiction. The key feature may be the search difficulty: When search is easy, for example in the case of sparse search arrays or homogenous textures (our Experiment 1), an early FE locus is found. In contrast, when search is made more difficult by increasing the density of the search array or by introducing a spatial jitter in a previously homogenous texture (our Experiment 2), the FE locus is shifted to a later processing stage.

The component that was affected by familiarity in both experiments was the mid-early N2p. This component occurs after the N1 and prior to the P3. Since we found a modulation by familiarity, we conclude that not only the orientation differences but rather the whole symbols (including their meaning) were evaluated at this processing stage in both experiments. This is again in line with the findings by Zhaoping and Frith (2011) who found an effect of familiarity after the first gaze shift (in both of their experiments). In particular, Zhaoping and Frith (2011) found that participants in the ‘familiar target’ condition performed more eye movements around the target before they gave their response. It, therefore, appears

that both eye movement and ERP data suggest that in any case familiarity affects the later visual processing.

In Experiment 2, in which inhomogeneous textures were used, we also found effects on the late P3 component. In this experiment, the stimuli were made somewhat more difficult by adding a spatial jitter to the individual elements of the texture stimuli. It is not entirely clear how to interpret the finding that we did not find a P3 effect in Experiment 1. We know that adding a jitter will enhance the FE. One interpretation for this effect is based on the assumption that the measurement of the P3 amplitude is less reliable and, thus, only a bigger FE will have an impact. The second interpretation assumes that both mid-early (N2p) and late stages (P3) contribute to the FE, but the P3 component will only come into play when the whole performance is sufficiently slowed down by the jitter. In this case, an FE in the P3 component will be found and the FE in the behavioral measures is enhanced. We assume that both interpretations are possible and equally plausible given the current set of data. The P3 is often related to task difficulty (e.g., Kok, 2001). The difference in the P3 latency between Experiments 1 and 2 might be due to an increase of task difficulty in Experiment 2 as compared to Experiment 1 due to the jittering of the textures (Kehrer, 1987; Gurnsey & Browse, 1989). Alternative interpretations of the P3 have been suggested, though. Schubö et al. (2001) relate the P3 to attentional resources, Donchin and Coles (1988) argue that P3 is involved in memory updating and Verleger, Jaśkowski and Wascher (2005) assume a role of P3 in mediating between perceptual analysis and response preparation. Our findings do not allow us to support or refute any of these interpretations.

Furthermore, we demonstrated that the reaction time advantage of the ‘unfamiliar target’ display does not simply reflect a preference for a given line-orientation, thereby strengthening the claim that FE reflects prior knowledge and prior visual experience. These findings are also in line with a suggestion made by Zhaoping and Guyader (2007). In their

study Zhaoping and Guyader (2007) demonstrated that when searching for a line with a unique orientation performance slows down when a second set of horizontal or vertical lines is superimposed in such a way as to form objects in combination with the first set of tilted lines. The slowing is more pronounced when the form of the object with the target line is similar to objects with distractor lines. Moreover, the slowing is reduced for shorter presentation times. Zhaoping and Guyader (2007) conclude that object-based information interferes with the detection of simple (low-level) features. Furthermore, it seems that object-based processes take more time so that these object-based effects are seen more clearly for conditions with longer presentation times. Zhaoping and Guyader (2007) argue that this account could also explain aspects of the FE. The assumption is that the FE reflects asymmetrical object-based interference with low-level feature detection. The objects in this case are the familiar or unfamiliar letters, the low level features can be tilted lines that form the letters and allow the distinction between target and non-target letters. This account of the FE predicts that the asymmetry occurs only when the lines are combined to letters and does not occur when the tilted lines are presented alone. We confirmed this prediction in Experiment 1. Zhaoping and Guyader (2007)'s account also predicts that object-based interference is more pronounced in conditions requiring longer processing times. Accordingly one can predict that FE is also enhanced in such conditions. This prediction is supported by Meinecke & Meisel, 2014, who found increased FE when spatial jitter is added. Moreover, the assumption that influences from high-level processes, such as object-based and knowledge-based interference, develop over time and will be primarily seen in tasks with longer processing times is also supported by our finding of FE-modulation of the P3 component in the segmentation task with spatial jitter (Exp. 2) but not in the task without jitter (Exp. 1). In summary Zhaoping and Guyader (2007)'s account of FE is broadly

supported by our findings and in particular provides a useful explanatory framework for our EEG-findings.[1]

Our study is subject to some limitations. In our first experiment, we adjusted stimulus presentation times individually for each participant. This was done with the aim to achieve high hit rates and to get the same number of trials for each participant. It might be that this increased the amount of noise in the data. In the second experiment, the same presentation

[1] Our study is also interesting in the context of the claim by Rosenholtz (2001) who suggested that many so-called search asymmetries reveal rather less about the processing of features in the visual system than previously thought. Rosenholtz argues that performance differences for opposite but seemingly symmetrical search displays can often be explained by basic asymmetries in features used for the paired displays. A classic example of a search asymmetry is the finding of faster search times for a moving target among stationary distractors as compared to searches for a stationary target among moving distractors (Dick, Ullman & Sagi, 1987). Rosenholtz (2001) points out that in the more difficult case, the distractor set is more heterogeneous, i.e. there are many more ways a moving distractor can be moving (e.g., to the right, left, up, down) than for a stationary distractor to be stationary. This means that the two search types are not symmetrical and that the performance asymmetry, thus, merely confirms this basic asymmetry in the composition of the search display. In the context of our study, the question, thus, arises whether the 'familiar'/'unfamiliar' asymmetry might also be caused by a more basic asymmetry in stimulus features used to compose the two contrasting displays. However, we assume that it is unlikely that the 'familiar'/'unfamiliar' asymmetry can be easily reduced to asymmetries in feature space. First, it should be noted that the asymmetry is not restricted to the stimuli used in our study has been found in a variety of cases with different features with the only commonality being the familiarity versus unfamiliarity of the employed stimuli (e.g., Wolfe, 2001; Malinowski & Hübner, 2001; Shen & Reingold, 2001). Second, we used a texture segmentation task and not a search task. The important difference here is that in texture segmentation it is not just the distractors that are presented in great number but also the target elements. Accordingly, any confounding asymmetry that is introduced by virtue of one type of feature being open to more variability (e.g., moving targets) than the other type of feature (e.g., stationary target) can be avoided or at least be reduced in the texture segmentation case. Last, and this is the part where our findings become relevant, the only obvious local feature difference in our case is the tilt of the connecting line in the two letters. Since we could show that a display consisting only of such tilted lines does not produce the type of asymmetry observed for the letters, we are confident that the critical aspect for the found search asymmetry is not related to the visual features of the letters but to the previous experience of observers with one letter but not the other one. Thus, our findings strengthen the claim that the FE is based on prior visual experience and knowledge and that it does not reflect a more basic asymmetry in visual feature space.

time was used for all participants. This led to different hit rates for different participants (that reflected the FE) and consequentlya different number of correctly answered target-present and target-absent trials. This may have affected the results of our statistical analysis. Another limitation is that we used a block design. This means that the identity of the target was known before the start of each trial. This may have led to a specific search strategy (e.g. activation of a target-defined search template or suppression of a non-target-defined search filter) which may have allowed participants to speed up the search process. Such effects were found by Zhaoping and Guyader (2007). They demonstrated that participants produce shorter reaction times when trials are presented in a blocked design. Shorter reaction times indicate shorter processing times. This may explain why we found in our study (Exp. 1) FE modulation for early ERP components. It would be interesting to see whether a different pattern of EEG-findings emerged when trials using different targets were presented in an interleaved fashion.

Before we conclude, we should briefly discuss whether the findings in our study can be expected to generalize to other tasks such as visual search and to other ERP components. While texture segmentation shares some features with efficient visual search, the underlying physiological processes are not the same (Schubö, Schröger & Meinecke., 2004). At present, it remains also unclear whether our findings extend to textures with more complex stimuli that are not defined by basic features. There is in fact some evidence that familiarity might affect even earlier ERP components when more complex stimuli, such as faces are employed (Rossion, Gauthier, Goffaux, Tarr & Crommelinck, 2002; Rossion, Joyce, Cottrell & Tarr, 2003).

6 Conclusion

Our study confirms that familiarity can affect texture segmentation. In addition to earlier findings, we could demonstrate that the N2p was consistently affected by familiarity. The earlier N1 component was only affected for homogeneous textures. When a spatial jitter was introduced to strengthen the FE, the late P3 component was also modulated by familiarity. Taken together, these findings suggest that visual experience can shape the mechanisms and the filters of the early perceptual stage in texture segmentation and that stronger influences of familiarity shift the FE occurrence to later ERP components.

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Table legends

Table 1. Overview of experimental conditions in Experiment 1 and Experiment 2. In the pre-test, the same conditions as in Experiment 1 were examined.

Table 2. Mean Peak latencies and amplitudes for Experiment 1 (homogeneous textures) for the 'unfamiliar target', 'familiar target', 'left-tilted lines', and 'right-tilted lines' conditions.

Table 3. Mean Peak latencies and amplitudes for Experiment 2 (jittered textures) for the 'unfamiliar target' and 'familiar target' conditions.

Tables

Table 1.

Condition	Target	Background	Label
1 (Exp. 1 & 2)	N (normal N)	И (mirror N)	‘familiar target’
2 (Exp. 1 & 2)	И (mirror N)	N (normal N)	‘unfamiliar target’
3 (Exp. 1 only)	\ (left-tilted)	/ (right-tilted)	‘left-tilted lines’
4 (Exp. 1 only)	/ (right-tilted)	\ (left (tilted)	‘right-tilted lines’

Table 2.

Condition	Target presence	N1 latency M ± SE (ms)	N1 amplitude M ± SE (μV)	N2p latency M ± SE (ms)	N2p amplitude M ± SE (μV)	P3 latency M ± SE (ms)	P3 amplitude M ± SE (μV)
Unfamiliar target	target-absent	147.4±3.0	-3.2±1.4	282.1±2.8	1.6± .7	419.6±9.6	5.8±0.5
	target-present	144.5±2.3	-3.4±1.3	276.3±3.0	2.9±1.0	405.8±8.8	9.9±1.0
Familiar target	target-absent	145.2±2.4	-3.8±1.5	278.8±3.0	2.1±0.7	420.3±7.0	6.4±0.7
	target-present	144.6±2.3	-4.1±1.4	274.9±3.6	4.5±1.0	395.4±8.1	11.0±1.0
Left-tilted lines	target-absent	144.9±4.0	-3.6±1.1	290.4±3.3	1.9±0.7	415.5±7.2	7.0±0.7
	target-present	146.3±4.4	-4.1±1.2	275.8±3.1	7.4±1.0	375.3±6.5	11.4±1.0
Right-tilted lines	target-absent	141.8±3.6	-3.8±1.2	293.7±3.1	1.1±0.8	418.1±5.5	7.0±0.8
	target-present	141.7±3.6	-4.0±1.2	277.3±4.2	7.0±1.1	376.7±6.9	11.6±1.0

Note. M: mean, SE: standard error.

Table 3.

Condition	Target presence	N1 latency M ± SE (ms)	N1 amplitude M ± SE (μV)	N2p latency M ± SE (ms)	N2p amplitude M ± SE (μV)	P3 latency M ± SE (ms)	P3 amplitude M ± SE (μV)
Unfamiliar target	target-absent	139.3±4.2	-6.3±1.0	268.0±6.3	1.4±1.2	368.1±7.9	4.6±0.9
	target-present	142.6±4.1	-6.0±0.9	268.0±5.9	2.2±1.0	384.4±8.6	8.2±0.9
Familiar target	target-absent	142.5±4.2	-6.7±0.8	276.6±4.5	2.4±1.0	378.4±7.6	4.8±0.8
	target-present	142.5±4.4	-7.0±0.8	276.9±3.9	4.6±0.8	392.3±5.5	10.3±1.0

*Note.*M: mean, SE: standard error.

Figure legends

Figure 1. Examples of stimuli containing a target for the 'familiar target' (a), the 'unfamiliar target' (b), 'left-tilted target' (c), and 'right-tilted target' (d) conditions. The figures show only a part of the actual stimuli.

Figure 2. Pre-test of Experiment 1. Hit rates for the 'familiar target' and the 'unfamiliar target' conditions: (a) and the 'left-tilted lines' and 'right-tilted lines' conditions (b) The eccentricities under which an FE was found between the 'familiar target' and 'unfamiliar target' conditions are encircled. Error bars indicate mean standard errors.

Figure 3. Time course of Experiment 1. The stimulus presentation time was adjusted individually up to 141.2 ms.

Figure 4. Experiment 1, 'familiar target' and 'unfamiliar target' condition. Averaged ERPs at Pz, POz, and Oz, presented separately for target-absent and target-present trials for the 'familiar target' (a, c, e) and 'unfamiliar target' (b, d, f) conditions. The mean amplitudes for the three ERP components are presented in panels g-i.

Figure 5. Experiment 1, 'left-tilted lines' and 'right-tilted lines' conditions. Averaged ERPs at Pz, POz, and Oz presented separately for target-absent and target-present trials for the 'left-

tilted target' (a, c, e) and 'right-tilted target' (b, d, f) conditions. The mean amplitudes for the three ERP components are presented in panels g-i.

Figure 6. Example stimuli of the 'familiar target' condition (a) and the 'unfamiliar target' condition (b) used in Experiment 2. The figures show only a part of the actual stimuli.

Figure 7. Experiment 2. Averaged ERPs at Pz, POz, and Oz, presented separately for target-absent and target-present trials for the 'left-tilted target' (a, c, e) and 'right-tilted target' (b, d, f) conditions. The mean amplitudes for the ERP components are presented in panels g-i.